Developing the Ability to Map In situ Optical Properties in Coastal Waters using Slocum Coastal Gliders

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LONG-TERM GOAL

Characterizing *in situ* water turbidity is critical to numerous naval operations. In particular, water column turbidity impacts the efficacy of sensors that use optical measurements for a variety of purposes including laser detection of mines and prediction of the operational detection horizon for bioluminescence. A covert autonomous platform outfitted with an optical sensor package and capable of reporting the data in near-real time prior to and during advance into a battle space has been identified by ONR as a highly desired tool. To this end we are developing a long duration autonomous vehicle for collecting in-water turbidity measurements. The endurance, water column coverage, stealth, and mobility of the Slocum Coastal Glider create an ideal platform when coupled with the correct optical suite.

OBJECTIVES

We intend to develop an autonomous platform capable of providing optical measurements in near real-time. The data stream from the sensors will provide the data on water column turbidity, which will feed system performances models allowing optimal use of Naval assets during field operations. Specifically we propose to 1) In collaboration with Wetlabs integrate a miniaturized scattering attenuation meter (SAM) into a two Gliders, 2) to deploy the SAM-Glider off the coasts of New Jersey, Massachusetts, Virginia, and the western coast of Florida in preparation of JTFX, 3) develop onboard processing of SAM data on the Glider computer to facilitate the use of the data by Naval system performance models (in collaboration with Metron) and 4) partake in the June 2004 JTFX.

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14. ABSTRACT
Characterizing in situ water turbidity is critical to numerous naval operations. In particular, water column turbidity impacts the efficacy of sensors that use optical measurements for a variety of purposes including laser detection of mines and prediction of the operational detection horizon for bioluminescence. A covert autonomous platform outfitted with an optical sensor package and capable of reporting the data in near-real time prior to and during advance into a battle space has been identified by ONR as a highly desired tool. To this end we are developing a long duration autonomous vehicle for collecting in-water turbidity measurements. The endurance, water column coverage, stealth, and mobility of the Slocum Coastal Glider create an ideal platform when coupled with the correct optical suite.

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APPROACH

The newly developed Wetlabs Scattering-Attenuation System (SAM) is small and robust. It is capable of measuring b_b, b_s, c and fl. The system will be developed and integrated into the Glider. The data collected by the Glider (including the SAM, CTD, and altimetry data) will be delivered to shore via Iridium and/or RF modem when ships are nearby. Data is processed and delivered to Metron allowing system performance models appropriate for mine counter measures to be run in near real-time.

WORK COMPLETED

The SAM sensor has been successfully integrated into the 2 Webb Slocum Gliders (Figure 1). The SAM glider has been deployed and field tested 1) in the waters of New Jersey, 2) off the coast Massachusetts as part of the ONR sponsored C-Blast exercise, and 3) off the coast of Virginia in the recent Mine Warfare Readiness and Effectiveness Measuring (MIREM) effort before and after Hurricane Isabel. The data collected has been distributed to Metron for testing their system performance algorithms. Data from the MIREM effort was also distributed to both Mark Reynolds (Anteon Inc.) and the Commander of the Surface Warfare Development Group in Norfolk Virginia. At the request of NAVOCEANO and the Surface Warfare Development Group we also deployed an optical/CTD instrument cage containing a Wetlabs ac-9, Satlantic spectral radiometers (downwelling irradiance, upwelling radiance), FSI CTD, and a Wetlabs EcoVSF. To facilitate efforts for the upcoming JTFX effort a hand held Iridium phone has been linked to a portable computer to provide operators in the field a portable command center.

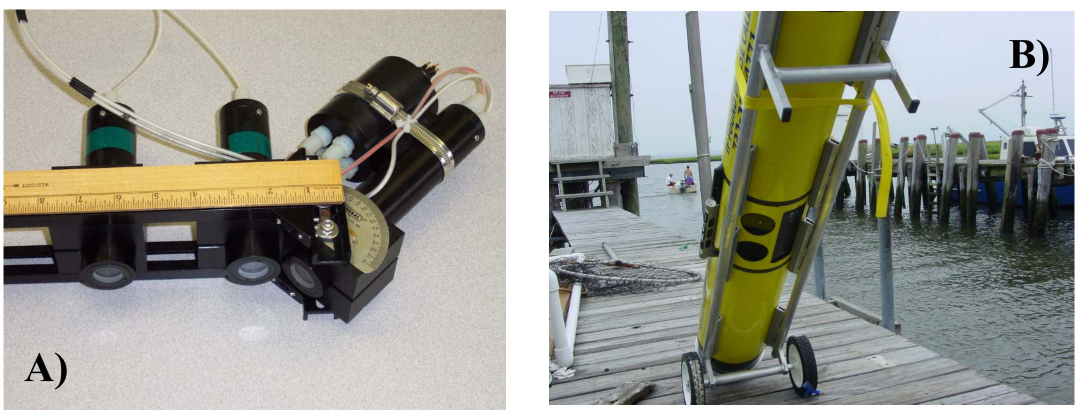

Figure 1. The SAM sensor prototype (A) and the integrated package in a Slocum Glider (B)

RESULTS

CBLAST and LEO Deployments After initial integration tests off the docks of Rutgers Marine field station (Figure 1B), the SAM Glider was deployed during the CBLAST exercise. The SAM glider complemented a Glider deployed simultaneously as part of the Coastal Ocean Modeling and Observation Program (COMOP), which was deployed off the Martha's Vineyard Observatory and off the coast of New Jersey. The SAM Glider was deployed successfully twice during that field effort. The Glider SAM data was calibrated by a profiling instrument cage, deployed by Mike Twardowski of Wetlabs (Figure 2). The Glider was deployed in several locations in Buzzards Bay in order to assess the variable presence of bottom nephaloid layers. The presence of nephaloid layers were clearly present and were sufficient in strength to impact both diver visibility and optical mine detection systems (see Figure 3 for examples of the nephaloid layer impacts on Diver visibility). The data was calculated by Wetlabs and has been distributed to Metron.

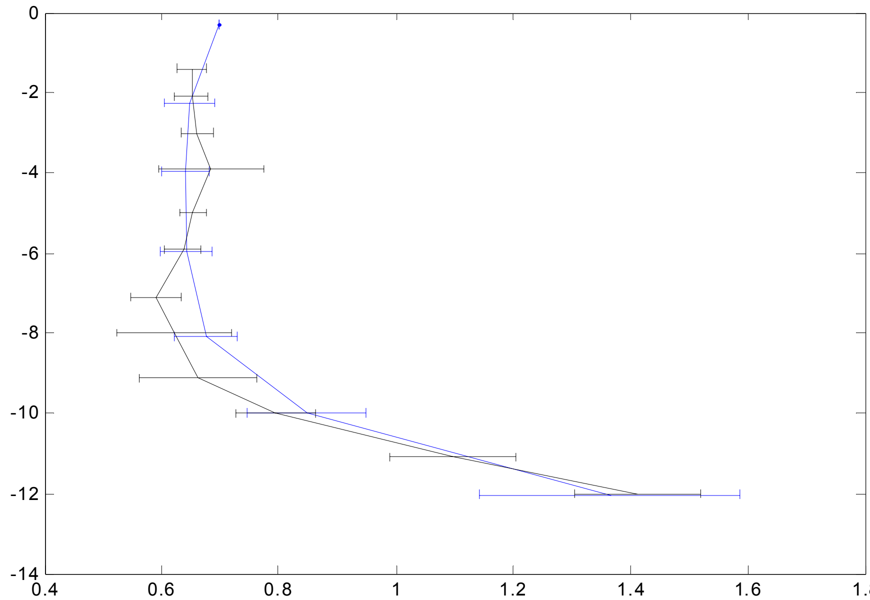

Figure 2: Glider SAM data showing attenuation at 650nm(blue compared to ac-9 attenuation at 650nm (black).

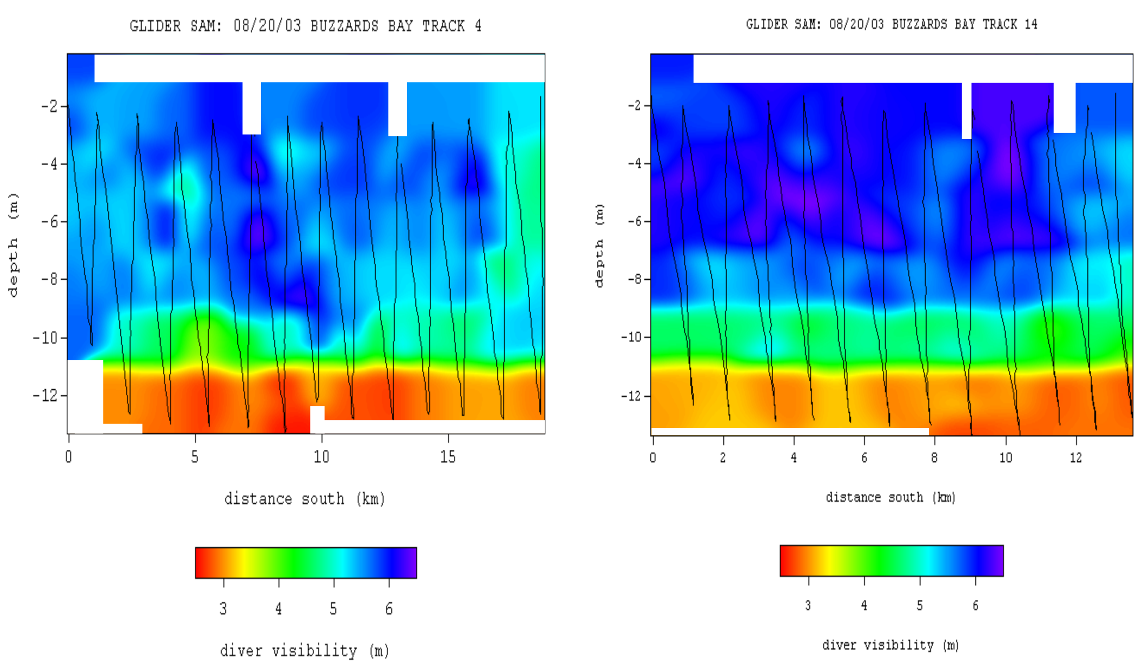

Figure 3. Data from two of 14 transects collected by the SAM-Glider in Buzzards Bay. The attenuation data [650 nm, c_{pg}(650)] was used to estimate horizontal diver visibility according the semi-analytical algorithm of Zaneveld and Pegau.

MIREM Deployments: The MIREM deployments were conducted in collaboration with NAVOCEANO, the Surface Warfare Development group, Metron, Anteon, and the HM-14. The two-week effort was disrupted by the passage of hurricane Isabel, which resulted in the fleet being ordered to sea. After the ordered evacuation of Virginia Beach was lifted, we redeployed field assets for a two-day effort. During that period both the shallow and deep mine lay sites were sampled both with a

SAM Glider and with an instrument cage as requested. The deep-water site exhibited an upper mixed layer depth of ~ 17m with high turbidity water near the bottom (Figure 4). The shallow water site exhibited high turbidity in the near surface and in the bottom waters. The surface turbidity layer was associated with low salinity water (Figure 4). The shallow water station provides the unique condition where a diver near the surface will be visible at 7 ft but the will be visible at 14 ft at a 6-8 meter depth. Near the bottom the diver will be visible at only 4 ft away.

Glider collected data at both mine lay sites has been passed to all partners. As with the ship instrument cage the presence of the bottom nephaloid layers was visible (Figure 5). Nephaloid layers extended 1-2 meters, on average, above the bottom and routinely represented a four-fold increase in the water turbidity. These layers represented the most optically dominant features at both the shallow and deep-water sites. As before, there was good agreement with the ac-9 and the SAM Glider data. We are confident that the SAM sensor provides good quantitative attenuation data and unlike a beam attenuation sensor the SAM system provides a measurement of an inherent optical property allowing for robust radiative transfer modeling.

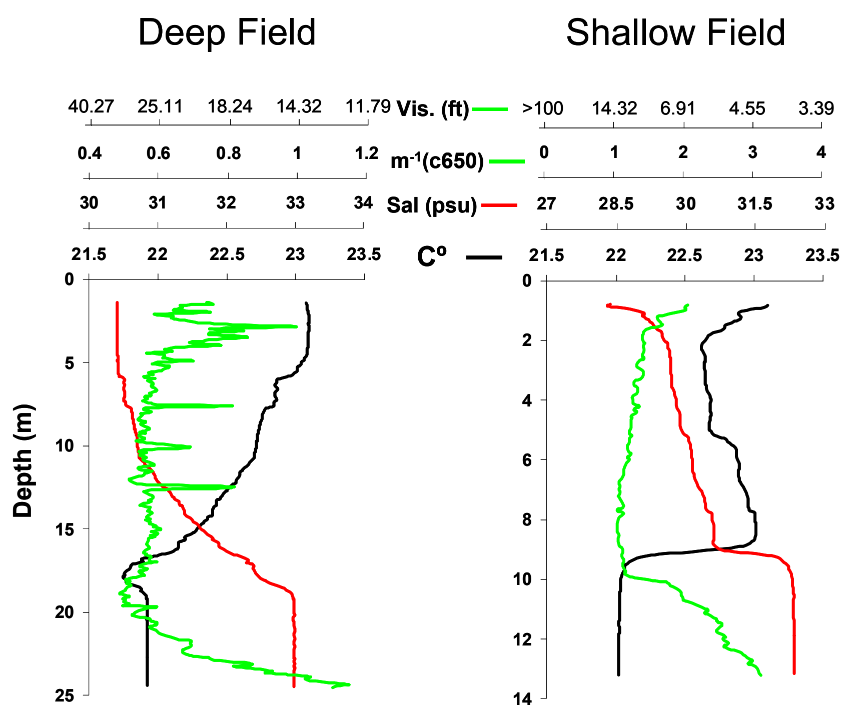

Figure 4. Environmental data collected during the MIREM exercise on September 25th and 26th 2003. Diver visibility was calculated using the Pegau and Zanveld algorithm.

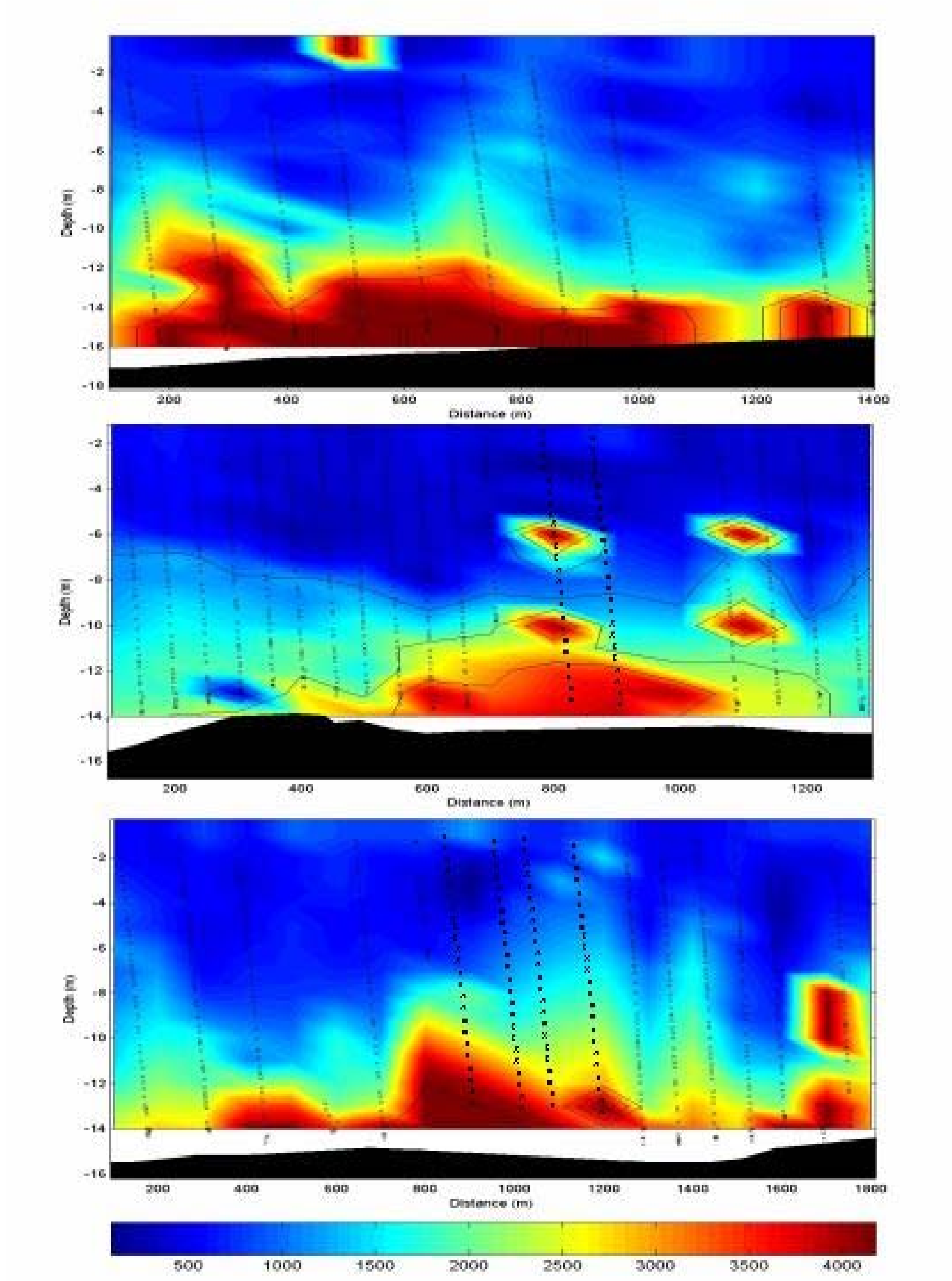

Figure 5. Transects collected using the SAM Glider at the shallow water site during MIREM collected on September 26th 2003. . Data is raw instrument counts.

IMPACT/APPLICATIONS

The Navy's mission has transitioned from a deep blue water tactical theatre to a littoral environment; however present Naval operational capabilities do not have the required data fidelity to deal with the complexity of coastal waters. These shortcomings are compounded as traditional sampling approaches are quickly compromised in denied access regions. The development of a long duration covert capability for collecting environmental (hydrographic and optical) data will offer a new paradigm in solving this problem. Using mine counter measures as an example, optical data would feed back on submersed and aircraft laser line scan mission planning by impacting the effective depth at which the laser can "see". If the environmental characterization is performed over relevant scales the applications will assist real world missions, including mine detection and mine-counter measures, Special Forces operations, amphibious landings, shallow water anti-submarine warfare and force protection from terrorism.

TRANSITIONS

The data is being freely shared with Metron, Anteon, Surface Warfare Development and NAVOCEANO. Data will be disseminated to the ONR WOOD database. Data will be burned to data CD's and will be made available via one-way FTP. Ongoing field efforts in Fall 2003 and Winter 2004 will distribute data in real-time over the world-wide-web (currently the site routinely has over 100,000 hits/day) by the general public, Naval METOC groups, NAVO, NOAA, and the U.S. Coast Guard. The SAM sensor has been field-tested and calibrated with standard optical instrumentation and appears to be a robust sensor ideal for AUV applications.

RELATED PROJECTS

This project has provided data directly to the ONR sponsored Coastal Ocean Modeling and Observation Program (COMOP) during the CBAST deployments in summer 2003, 2) has complemented ongoing optical efforts for the Hyperspectral Coupled Ocean Dynamic Experiment (HyCODE), 3) supported the MIREM exercise and filled in data gaps when the battle space profiler was unavailable. The SAM Glider will deployed as part of ONR/NASA sponsored efforts to develop red-tide algorithms in a cruise being conducted November. Finally this effort represents a significant extension of ONR-STTR funded efforts awarded to Webb Research and Wetlabs. Efforts in the coming year will be focused on taking part in the JTFX field effort.

PUBLICATIONS RESULTING FROM GLIDER SUPPORT

Schofield, O., Bosch, J., Glenn, S. M., Kirkpatrick, G., Kerfoot, J., Moline, M., Oliver, M., Bissett, W. P. Harmful algal blooms in a dynamic environment: How can optics help the field-going and sample poor biologist? In Real Time Coastal Observing Systems for Ecosystems Dynamics and Harmful Algal Blooms. Babin, M. And Cullen, J. J. (Eds) UNESCO, Paris. (submitted).

Glenn, S., Schofield, O. Observing the Oceans from the COOLroom: Our History, Experience, and Opinions. Oceanography (submitted)